Interview with Ian Sloan

September 3, 2012, in Sydney (Ian Sloan) and Singapore (Peter Hall)

Peter Hall

Introduction. Ian Hugh Sloan was born in Melbourne on June 17, 1938, and educated at Scotch College, Melbourne, and Ballarat College, before going on to undergraduate degrees in physics and mathematics at the University of Melbourne. Shortly after completing his BSc and BA (Hons) in late 1960 he joined the Colonial Sugar Refining Company. This might sound like an inauspicious start for a research mathematician, but by the early 1940s, CSR, as it is called today, had already diversified into building products and chemicals, and by the late 1950s had plans for a future based largely on scientific research. Thus, Ian was able to undertake a PhD in theoretical atomic physics at University College, London while receiving a salary from CSR.

However, when Ian returned to Australia in 1964 he found a changed CSR. In particular, the research project on which he was supposed to work had collapsed, and his employer was more focused on short-term, rather than long-term, goals. So he left, and joined the University of New South Wales in 1965, and has been there ever since. Over the ensuing 48 years he has developed and fostered Australia's premier numerical analysis programme.

Ian, and many of the students from that programme, have gone on to win major awards for their work. For example, Ian was elected to the Australian Academy of Science in 1993. Some of his students have first spent time working for business and industry, returning to academia to do a PhD a few years later with new insights and motivation. He has held an Australian Research Council 'Linkage' grant with Macquarie Bank. This two-way connection between the UNSW numerical analysis programme and business and industry is one of the programme's many successes. Two other highlights of his career include his Presidency of the International Council for Industrial and Applied Mathematics, and Headship of the UNSW School of Mathematics.

Ian has also given a great deal back to the profession. His outlook has always been positive and inclusive, and his presence on selection and review committees, or in groups developing long-term plans for the profession, is often sought. Many mathematical scientists working in Australia have benefited from his work on behalf of our community.

Peter Hall: Thank you, Ian, for agreeing to this interview. I'm sorry that we can talk only by Skype on this occasion, although we know each other well through many other meetings. In fact, I know quite a bit about your recent career and your work, but almost nothing about your more distant past. Perhaps we could start there.

Ian Sloan: I was born in 1938, into a long-established Melbourne family. Indeed, all my forebears, as far as I know, were in Australia by the 1850s, all having come from the United Kingdom. The first arrival seems to have been my ancestor Francis Feild [sic], who, as some of the family's historians were to claim, was captain of one of the convict ships. However, my favourite aunt discovered that this was a polite exaggeration. In truth, Francis arrived in 1819 as part of the convict cargo, transported from England for larceny. The exotic spelling of his surname was also an invention of Victorian times, part of the process of upward mobility.

By the time I was born the family was respectably Presbyterian, and my father was senior mathematics teacher and House Master in the senior boarding school at Scotch College in Melbourne. He was an outstanding sportsman, as well as a keen scholar. He trained as a

Peter Hall and Ian Sloan

civil engineer, but had one of the shortest engineering careers on record, since he lost his first job after only a few weeks, at the start of the Great Depression. He always claimed that losing his engineering job was the best thing that could have happened to him, because he then began the career he was made for, namely that of being a mathematics teacher. He loved teaching, and was the finest of teachers.

Somehow my father and mother managed to find funds to take the two of them to Cambridge, where he completed the mathematics tripos, before returning to Australia in time to beat the outbreak of war. My brother Charles, my only sibling, was born in the UK, and I was born shortly after the family's return to Australia.

I spent the first four years of my life roaming freely in the glorious grounds of Scotch College, being in paradise but not knowing it. The world was at war, but Melbourne was far away from it. All I wanted to do was to get over the fence into the infants' school, which happened to be next to the part of the boarding house where we lived. As a result, I suppose, of my constant pressure, I started school a few days after I turned four. I revelled in it.

At the age of six my father was appointed Principal of Ballarat College, so I spent most of my school years in Ballarat, a hundred kilometres west of Melbourne. I did well academically, revelling in mathematics, science, history (we had a great history teacher), English language and literature. I studied Latin and French for a number of years, but failed to be inspired by Latin.

A downside to being at a country school was the limited offerings: after my first matriculation[a] year, because I was still only 16 (remember that I started when I turned four), I repeated that year, this time taking pure mathematics by correspondence, because it (unlike calculus and applied mathematics, taught by my father) was not offered at my school. Moreover,

---

[a]In this context, "matriculation" means "becoming eligible to enter university by virtue of having passed appropriate subjects at school, at the appropriate levels."

being the Principal's son in a small and isolated country town (as Ballarat was in those days) was not without its problems, as you can imagine.

PH: The next stage in your career was your degree at the University of Melbourne, I believe. But perhaps first you could tell us a little about your brother, who I think was two years ahead of you.

IS: Charles took after my father, in that he was an outstanding sportsman. However, unlike my father he was not academically inclined. I was always a little jealous of the relationship he had with our father through his sporting prowess. Later I learned that he was jealous of the relationship that I enjoyed on account of our shared love of things of the mind. I played sport at school, but I was never very good at it.

Charles matriculated by way of a diploma at an agricultural college, and then went on to study veterinary science at the University of Queensland. He worked first as a large animal vet in Gippsland, in the state of Victoria, and then moved to Queensland. He also served as government vet on King Island, between the Australian mainland and the island state of Tasmania, where he learned to fly. Sadly, he died ten years ago.

PH: Now let's turn to your time as an undergraduate. Living in Melbourne must have been a bit of a change after years spent in a rather isolated country town.

IS: Yes, being released from being the smartest kid in a small country school, and the Principal's son, gave me a wonderful sense of freedom. I loved university, but not always for the right reasons. I went into Ormond College, a college of the University of Melbourne, and loved it from the first. I knew hardly anybody, but it didn't matter. Some of the friends I made there are friends still.

My first degree was in physics, which I enjoyed, but thought was taught poorly. I especially remember that in the third and final year of the undergraduate degree we studied 24 units in eight-week blocks. Because each block was examined immediately, and could then be forgotten, the effect for me was (as I discovered when later I did a physics PhD) that I retained almost nothing. I had later to learn quantum physics again, from scratch.

Mathematics, on the other hand, was taught in a serious and systematic manner, although in a rather boring style. Nevertheless, I remember being very excited about real and complex analysis, and the extraordinary way in which one result builds on another to yield an amazing outcome.

By the time I was in second year I was in a somewhat wild phase of my life, and in a decision that I still find astonishing, some three weeks into the year, I dropped applied mathematics. This was possible because Melbourne University, at that time, had the remarkable flexible rule that in second year you could, if you wished, study two subjects rather than three. (I kept on with pure mathematics and physics.) I finished my first undergraduate degree, majoring in physics, in 1958.

PH: What happened then? In those days there were many opportunities in Australia for someone with a good science degree.

IS: As you say, jobs were so plentiful that I didn't have to worry. As so often happens, a serendipitous meeting had a major influence on my future career. Some time before the final exams, and still having no idea what to do next, I had a lucky meeting with E R (Russell) Love, Professor of Pure Mathematics at Melbourne University, and a family friend (my father having known him in Cambridge). Russell suggested to me that I might like to spend another two years to complete an Honours degree in pure and applied mathematics. My response was that I couldn't do that because I hadn't completed even second year applied mathematics. He said, in effect, you can do second and third year simultaneously. So that is what I did. I shall remain always grateful for his superb flexibility in interpreting the academic rules.

I still have mixed feelings about those two years. I gained a real feeling for analysis, but nowhere did I learn that one could do research in mathematics!

PH: Doing second and third year together sounds like a lot of hard work, not to mention stress and pressure.

IS: Well, it wasn't all bad — not at all! One of the excellent outcomes of those two years was that I met my future wife, Jan. She was an athlete, a member of the university athletics club, who was studying occupational therapy, largely at the University of Melbourne. Her love and support, and the family that we have together, have been a constant source of strength and enjoyment throughout my career.

Indeed, let me digress a little on this subject, if I may. Jan and I have two wonderful, successful children, neither of whom showed any inclination to follow their father into an academic career. Our daughter, Jennifer Johnson, trained as physiotherapist and public health administrator (she has both a physiotherapy degree from Sydney University and a Master of Public Health

Administration degree from UNSW), and is now the coordinator of a large pain management initiative of the NSW Department of Health. Our son, Tony Sloan, with a commerce degree from UNSW, is a corporate tax partner with a large accounting firm. Jan and I are blessed with six lovely grandchildren, all of whom have the good sense to live in Sydney!

PH: I didn't know that, in the 1950s, Honours degrees took two years. Ironically, just recently the University of Melbourne turned back, in a sense, to that style of programme — the one-year Honours degree, now common in Australian universities, has been replaced at the University of Melbourne by a two-year Masters degree.

But I digress. As you say, in 1960 you completed a BA (Hons) in mathematics at the University of Melbourne, but you still had little idea what you would do. What was the next step?

IS: I looked around for a job that would allow me to get married. I applied for three positions, at three different research laboratories, and was offered each of them. I took the one offered by CSR (then the Colonial Sugar Refining Company, a large Australian chemicals and building materials company). One attraction was that CSR would send me to London on a salary, to do a PhD in theoretical atomic physics. As it turned out, they even allowed me to spend the half year before the start of term doing a Masters Degree in mathematical physics, under H S (Bert) Green at the University of Adelaide.

In September 1961 I married, and set out for London after a honeymoon in Adelaide, chosen for the unromantic reason that I was able to qualify for a Master's degree if I put in an appearance for the third term; I qualified by taking my new wife for afternoon tea.

PH: How did you find life as a graduate student in London in the 1960s?

IS: In London I studied theoretical atomic physics under what passed for the supervision of Professor Sir Harrie Massey, at University College London. Massey was an Australian physicist who was very highly regarded by British and US space agencies.

However, his official duties left him little time for looking after students. I reckoned afterwards that I met him just six times during those years, the last time being for my oral exam, held in a taxi. By modern standards he was, of course, grossly irresponsible as a supervisor,

but the few occasions on which I did get to see him were always valuable. I would always prepare carefully for a meeting, knowing that the opportunities were rare, and then seek an appointment with his Secretary, often to be told: "Sorry, he has just left for a few weeks or months at Cape Canaveral."

Conditions for research students at University College, London, were generally poor. When I first arrived I did not even have a desk — I survived by using the library, and by borrowing the corner of another student's desk to put my books on. But I do think I learned in those days a certain tough-mindedness and independence of spirit.

London in the early 1960s was at the centre of the "Swinging Sixties," but apart from the enjoyable public scandals (Christine Keeler, the Profumo affair, and so on), we didn't know we were so privileged. However, we did have a great time with the music, drama and opera that was on offer. But time was always short, because I was supposed to finish (and did finish) my PhD in just two and a half years.

PH: Perhaps you can say a little about the computing environment in those days. I know that in 1964 the University of Melbourne bought an IBM 7044 machine, and computation in the UK must have been advancing too in those days.

IS: Yes, I was lucky that large mainframe computers were becoming available when I started my PhD. Perhaps I was also lucky (having heard many stories of the early users who spent all night nursing temperamental computing machines) that our machine was offsite. Every day we would prepare a paper tape to be taken to the Atlas Computer in Manchester, and wait for it to come back the next day. The delay, and the fragility of tape, were by modern standards annoying, but they did encourage a careful attitude to programming — if a single wrong character could cause a day's delay, one learned not to make mistakes.

PH: What happened post-PhD? Your research in London had been paid for by CSR, and they must have had some idea what you would be working on when you returned.

IS: Well, yes and no. Jan and I returned to Australia in early 1964 with baby in tow, and I started work, as always intended, in the research laboratories of CSR in Sydney. However, I quickly found that the research project on which I was supposed to work no longer existed, and that CSR had changed in many ways.

Perhaps I should say a little more about what CSR was like in about 1960, so you can appreciate the substantial changes that had occurred while I was away, and would continue over the next few years.

Keith Sutherland had joined CSR in 1959 as Director of Research, and at one point in the 1960s the company had about 150 staff, including about 50 graduates, in their research laboratories. They worked on a particularly wide range of problems in chemistry, physics, engineering and mathematics. However, my time in the UK had coincided with a decline, at least in the area where I was supposed to return to work. On returning to the company I was given the task of finding out what I could do that would make money for my employer, a task at which I proved to be a complete failure.

PH: Consulting the Australian Academy of Science's bibliographical memoir on Keith Sutherland, I find the following rather ominous description of CSR's transition during this era: "Towards the end of the 1960s there were changes in the directions in which [CSR] was developing . . . [CSR's] company and divisional management was shifting from men trained primarily in science, to men whose experience lay in economics, commerce and practical mining."

IS: Yes, I felt that I should leave CSR. I was rescued when I replied to an advertisement for casual lecturers in the School of Mathematics at the University of New South Wales (UNSW). I was interviewed by the remarkable Professor John Blatt, who asked why I would want to do casual lecturing when I could instead come and work with him full time. So I applied for, and was offered, a Lectureship at UNSW. I remember well Keith Sutherland's comment when I announced my intention to leave: "Well, we have to accept that some people are not cut out for research."

So, I joined UNSW in March, 1965, and I'm still there!

PH: You had been trained as a physicist, and at that time you perhaps did not think of yourself as a mathematician. But you joined a Department of Applied Mathematics. How did that work out?

IS: In those days the Department of Applied Mathematics was really a theoretical physics department in everything but name. All of the staff and research students were doing physics, and almost the only subjects we taught were from theoretical physics. And that was okay with me, because, as you say, I was a physicist too.

With John Blatt's encouragement I started to do research on few-body collision problems in nuclear physics, and it wasn't long before I was comfortably integrated into the Australian and international communities of nuclear theorists (by which I mean the properties and interactions of nuclei, not the generation of nuclear power). In the 1960s the great L D Faddeev had published his beautiful integral equations for three-body scattering, a prototype being the scattering of low-energy neutrons by deuterons. One of my contributions was to develop a set of analogous equations for four interacting particles, which were then generalised by G Bencze and E F Redish to N particles, and can still be found by Google Scholar as the Bencze–Redish–Sloan equations. But their interest has faded — they are just too hard to solve!

PH: At some point in your career you moved from nuclear physics to numerical analysis. Was this a conscious decision, or did it "just happen"?

IS: Yes, I have often been asked how and why I switched. Here is one version of the story. While working on nuclear scattering problems, I and others in the field became rather skilled at inventing methods for solving the integral equations of scattering theory. I decided in about 1973 that I would spread the message about these novel methods to a wider audience. So I wrote a paper on a new technique for solving second-kind integral equations, and submitted it for publication. The short story is that my paper was rejected, and the rejection made me a professional numerical analyst. A lengthier version is that the journal asked me to rewrite the paper in a way that I found unacceptable, as I thought rewriting it that way would bury important intuition, so I (successfully) submitted it elsewhere.

In a way I was right, but today I marvel at my arrogance: I was correct in wanting to keep the intuition, but I didn't deserve to have the paper published, as I had proved nothing! However, the main effect of the episode was to persuade me that I needed to learn some mathematics, of the functional analysis kind. And by the time I had written some integral equation papers with proofs, I was hooked.

I don't think I ever consciously decided to leave theoretical physics, but I did find myself more and more seriously engaged in mathematics, and never found the time or opportunity to go back.

PH: How would you define numerical analysis, and how, as a discipline, did it treat a strayed nuclear physicist?

IS: Numerical analysis is the science and art of taking the mathematically formulated problems of science and technology and converting them into computer-ready algorithms, with provable convergence and stability properties. It is not just about developing tricks for computer solution of problems, but also about understanding and exploiting approximation and stability properties. Viewed properly, it is at least as hard to study a converging sequence of finite-dimensional approximations as it is to study the continuous exact problem. Indeed one way to understand the exact problem is precisely to treat it as the limit of a sequence of discrete problems.

From the start I found numerical analysis and mathematics generally very accepting of a newcomer. To me it was important to get into the field quickly, as I was no longer a youngster. And at the start I knew not a single person who might be called a numerical analyst. There were some noted Australian numerical analysts at that time, but I had never met (or even heard of) any of them.

For me, a turning point was an invitation to give an invited talk at the 1976 Applied Mathematics Conference in Jindabyne. I have had many pleasant opportunities and rewards since, but for me this was a memorable experience — before then I had never been to a conference with mathematics in the title, or, since my undergraduate days, visited a department with mathematics in the title, except for my own.

You may say that physics is not so different from mathematics, but while that is true intellectually, socially they were worlds apart. It was almost like crossing the border from one ethnic group to another: one has to learn a new language and make a new circle of friends, because the two groups did not (and do not) speak to each other very much.

That Jindabyne conference was also a turning point for my community engagement with mathematics rather than physics. A year after that first conference I was the organiser of the 1977 Applied Mathematics Conference at Terrigal, and Editor of the Journal of the Australian Mathematical Society, Series B (now the ANZIAM Journal), which I worked hard to rescue from imminent oblivion — the previous Editor had resigned, with the recommendation that the journal be closed down. My involvement with the mathematics community, both in Australia and internationally, has gone on from there, and I have enjoyed it all.

PH: Even during this period your own work must have continued to evolve, and, despite the legendary barriers between scientific fields in Australia, your

earlier colleagues in physics must have kept in touch to some extent.

IS: Over the years the centre of gravity of my research has shifted a lot, even though to me the shifts often seem incremental. Originally I worked on the numerical solution of integral equations of the second kind, but over time that developed into an interest in so-called boundary integral equations (in simple terms, methods for studying and solving partial differential equations over a region by transforming them into integral equations over the boundary), and in turn into partial differential equations. Another major focus has been constructive approximation, often (especially in recent years) on manifolds. I have also always been interested in problems of numerical integration.

And I maintained some of my connections to physics, which for me was fortunate because at some point in the 1980s old friends in physics introduced me to exciting methods for high-dimensional numerical integration, developed originally by number theorists (Hlawka, Korobov, Sobol) in the 1950s and 1960s. High-dimensional problems now form a major focus of my research, and I think will be an important area of numerical analysis for many years. The mathematical underpinnings are interesting because successful methods in high dimensions cannot be based on classical methods of numerical analysis. High-dimensional applications also have the advantage of being very hard, and so will not quickly go away.

PH: Perhaps you could say a little about your perspective of mathematics today, as seen by a "lapsed physicist" who has made leading, highly influential contributions to numerical analysis. Your viewpoint would be unique, at least in Australia, and allow us to see through some of the barriers that normally divide one field of mathematics from another.

IS: I am immensely respectful of mathematics as a whole, but of course I know intimately only some parts of it. The primary corner for me is Numerical Analysis (number 65 in the AMS classification), but it is in no sense isolated, because it is related to so many other parts of mathematics. Let me mention some of the areas of mathematics that I have needed at one time or another in my research.

I start with analysis (real and complex, functional analysis, harmonic analysis), which is in many ways the foundation subject. So too is approximation theory. Partial differential equations, linear and nonlinear, are often vital. Algebra, especially group

representation theory, was very important for me in developing an understanding of "lattice" methods for high-dimensional numerical integration, and properly understanding the role of symmetry for problems formulated on the sphere. I have mentioned already the central role of number theory for high-dimensional integration. Many times I have used an argument that (for me at least) comes from number theory, namely that "there is always one case that is as good as average". Linear algebra naturally raises its head in the solution of every linear problem. And these days we need increasing amounts of probability theory. (Just recently I have been grappling with Robert Adler's old book on the geometry of random fields.)

Of course, I am not an expert in all, or indeed any, of these fields. I am an applied mathematician, which to me means that I am not seeking to make fundamental contributions to the fields mentioned above, but rather that I use all available mathematical tools to understand and analyse approximation schemes. And of course we also worry about the stability of our methods, because of the exaggerated rounding errors that come from using an unstable method. That means that we should be interested also in computer science, and computer architecture. I should mention also complexity, which is about the intrinsic difficulty of a problem, rather than about the cost of a particular algorithm.

I have not mentioned the most wonderful thing about numerical analysis, which is that after you have done some analysis, you can do the numerical calculations and see whether the results are as you predicted. It is always exciting to see predictions borne out in the numbers. It is even more exciting when the results are better than predicted — this means that there is more to prove! Alternatively, the results may be worse than predicted, in which case you have just received the priceless information that there is something wrong with either your theory or your calculations — or both.

PH: Your students too would enjoy your unique perspective. There have been many students; can you tell us a little about some of them and their careers?

IS: I had PhD students even in my theoretical physics days. One was Reg Cahill, now a Professor of Physics at Flinders University. With Reg I worked on scattering problems in nuclear physics. Another was John Aarons; we worked on nucleon-deuteron scattering and polarisation. My first student in numerical analysis was Ivan Graham, now a Professor at the University of Bath, with whom I am at present collaborating on topics completely different from those we worked

on years ago. Stephen Joe, now at the University of Waikato, was a student in those integral equation days and later a colleague in high-dimensional integration. His PhD student Frances Kuo (and so my doctoral grand-daughter) is now a valued colleague at UNSW. Though it is invidious to mention individual students, among those who have taught me much I mention Thanh Tran, now an Associate Professor at UNSW; Ben Waterhouse, now running his own consultancy company; and Josef Dick, also now a valued colleague at UNSW, and the winner of the inaugural Chris Heyde Medal of the Australian Academy of Science.

Four of my PhD students started careers in business or industry, but returned to academia to do PhDs. This outside experience has proved to be very beneficial for all of us, and reflects the many, many opportunities available today for mathematicians, particularly applied ones. If you are prepared to adapt then mathematics is, I would say, more versatile than other areas of science.

PH: *Your own students have done particularly well. So you are in a good position to give advice to the students of today. What would you say to them?*

IS: Ah, I am constitutionally wary about giving advice. On the other hand, I think my PhD students would say that I have firm views on many topics, views that are ground into my long-suffering students by the time I have finished with them! Perhaps the first piece of advice is to be very clear and accurate, and interesting in your papers and your talks. Every paper, every talk, should tell a good story. If the story is not compelling, why should anyone else be interested?

If you find something interesting, perhaps a discrepancy between what you expect and what you see in your calculations, drop everything and resolve the conflict. Perhaps you can progressively pin down the discrepancy between theory and calculation to a single step, and then test it thoroughly. Almost always this yields something important, even if it is only the realisation that something that you previously believed is in fact not true. On the other hand, this is sometimes the moment when you discover something new. That is a moment to savour (but only after you have done more work).

Do not give up too easily. Every advance is preceded by doubt (especially from other people). At some point every real advance needs courage — not of the supreme kind, but enough courage to press on when you believe something interesting is there, even though nobody else seems interested. Those of us who are somewhat senior have, I think, a responsibility not to be too discouraging in the way we say things.

Always seize opportunities to widen your range of expertise, so as to avoid the trap of working an area dry. Join with others, if each of you has something different to bring to a collaboration. Learn from your collaborators — I still do!

Finally, be generous professionally. If asked to referee, or serve on a committee, accept if you can, and do the job well. It is part of professional responsibility, and often lays the foundations for rewards of many kinds.

PH: *Thank you, Ian, for a particularly enjoyable and rewarding conversation. I note with great pleasure that you are still very occupied with mathematics. Indeed, it takes you around the world frequently. I hope, for the sake of mathematics, that this involvement will continue for a long time to come.*

Peter Hall
University of Melbourne, Australia

Peter Hall was born in Sydney, Australia, and received his BSc degree from the University of Sydney in 1974. His MSc and DPhil degrees are from the Australian National University and the University of Oxford, both in 1976. He taught at the University of Melbourne before taking, in 1978, a position at the Australian National University. In November 2006 he moved back to the University of Melbourne. His research interests range across several topics in statistics and probability theory.